THE BELL SYSTEM
TECHNICAL JOURNAL

A JOURNAL DEVOTED TO THE
SCIENTIFIC AND ENGINEERING
ASPECTS OF ELECTRICAL
COMMUNICATION

EDITORS

R. W. KING J. O. PERRINE

EDITORIAL BOARD

C. F. CRAIG
O. B. BLACKWELL
H. S. OSBORNE
J. J. PILLIOD
O. E. BUCKLEY
M. J. KELLY
A. B. CLARK
F. J. FEELY

TABLE OF CONTENTS
AND
INDEX

VOLUME XXVII

1948

AMERICAN TELEPHONE AND TELEGRAPH COMPANY
NEW YORK

PRINTED IN U. S. A.

THE BELL SYSTEM
TECHNICAL JOURNAL

VOLUME XXVII, 1948

Table of Contents

JANUARY, 1948

An Experimental Multichannel Pulse Code Modulation System of Toll Quality—*L. A. Meacham and E. Peterson* 1
Electron Beam Deflection Tube for Pulse Code Modulation—*R. W. Sears* 44
Metallic Delay Lenses—*Winston E. Kock* 58
A Non-reflecting Branching Filter for Microwaves—*W. D. Lewis and L. C. Tillotson* 83
A Note on a Parallel-Tuned Transformer Design—*V. C. Rideout* 96
Statistical Properties of a Sine Wave Plus Random Noise—*S. O. Rice* 109
Noise in Resistances and Electron Streams—*J. R. Pierce* 158

APRIL, 1948

Microwave Repeater Research—*H. T. Friis* 183
The Measurement of Delay Distortion in Microwave Repeaters—*D. H. Ring* 247
Frequency Shift Telegraphy—Radio and Wire Applications—*J. R. Davey and A. L. Matte* 265
Reflections from Circular Bends in Rectangular Wave Guides—Matrix Theory—*S. O. Rice* 305
The Approximate Solution of Linear Differential Equations—*Marion C. Gray and S. A. Schelkunoff* 350
Potential Coefficients for Ground Return Circuits—*W. Howard Wise* 365

JULY, 1948

A Mathematical Theory of Communication—*C. E. Shannon* 379
An Aspect of the Dialing Behavior of Subscribers and Its Effect on the Trunk Plant—*Charles Clos* 424
Spectra of Quantized Signals—*W. R. Bennett* 446
Analysis and Performance of Waveguide-Hybrid Rings for Microwaves—*H. T. Budenbom* 473
Methods of Electromagnetic Field Analysis—*S. A. Schelkunoff* 487
The Evolution of the Quartz Crystal Clock—*Warren A. Marrison* 510

OCTOBER 1948

Equivalent Circuits of Linear Active Four-Terminal Networks—*L. C. Peterson* 593
A Mathematical Theory of Communication (Concluded)—*C. E. Shannon* 623
Transients in Mechanical Systems—*J. T. Muller* 657
Maximally-Flat Filters in Wave Guide—*W. W. Mumford* 684
Transient Response of an FM Receiver—*M. K. Zinn* 714
Transverse Fields in Traveling-Wave Tubes—*J. R. Pierce* 732

Physics Lib.
M.
Bell Telephone Co

379
424
446
473
487
510
593
623
657
684
714
732

Index to Volume XXVII

B

Beam Transmission: Metallic Delay Lenses, *Winston E. Kock*, page 58.
Bennett, W. R., Spectra of Quantized Signals, page 446.
Budenbom, H. T., Analysis and Performance of Wave Guide Hybrid Rings for Microwaves, page 473.

C

Clock, Quartz Crystal, The Evolution of the, *Warren A. Marrison*, page 510.
Clos, Charles, An Aspect of the Dialing Behavior of Subscribers and Its Effect on the Trunk Plant, page 424.
Communication, A Mathematical Theory of, *C. E. Shannon*, pages 379–423; 623–656.
Crystal Clock, Quartz, The Evolution of the, *Warren A. Marrison*, page 510.

D

Davey, J. R. and A. L. Matte, Frequency Shift Telegraphy—Radio and Wire Applications, page 265.
Delay Distortion in Microwave Repeaters, The Measurement of, *D. H. Ring*, page 247.
Dialing Behavior of Subscribers and Its Effect on the Trunk Plant, An Aspect of the, *Charles Clos*, page 424.
Differential Equations, Linear, The Approximate Solution of, *Marion C. Gray and S. A. Schelkunoff*, page 350.
Distortion, Delay, in Microwave Repeaters, The Measurement of, *D. H. Ring*, page 247.

E

Electromagnetic Field Analysis, Methods of, *S. A. Schelkunoff*, page 487.
Electron Beam Deflection Tube for Pulse Code Modulation, *R. W. Sears*, page 44.
Electron Streams, Noise in Resistances and, *J. R. Pierce*, page 158.
Equations, Linear Differential, The Approximate Solution of, *Marion C. Gray and S. A. Schelkunoff*, page 350.
Equivalent Circuits of Linear Active Four-Terminal Networks, *L. C. Peterson*, page 593.

F

Field Analysis, Electromagnetic, Methods of, *S. A. Schelkunoff*, page 487.
Filter, A Non-reflecting Branching, for Microwaves, *W. D. Lewis and L. C. Tillotson*, page 83.
Filters, Maximally-Flat, in Wave Guide, *W. W. Mumford*, page 684.
Frequency Shift Telegraphy—Radio and Wire Applications, *J. R. Davey and A. L. Matte*, page 265.
FM Receiver, Transient Response of an, *M. K. Zinn*, page 714.
Friis, H. T., Microwave Repeater Research, page 183.

G

Gray, Marion C. and S. A. Schelkunoff, The Approximate Solution of Linear Differential Equations, page 350.
Ground Return Circuits, Potential Coefficients for, *W. Howard Wise*, page 365.

H

Hybrid Rings for Microwaves, Wave Guide, Analysis and Performance of, *H. T. Budenbom*, page 473.

K

Kock, Winston E., Metallic Delay Lenses, page 58.

L

Lenses, Metallic Delay, *Winston E. Kock*, page 58.
Lewis, W. D., and L. C. Tillotson, A Non-reflecting Branching Filter for Microwaves, page 83.

M

Marrison, Warren A., The Evolution of the Quartz Crystal Clock, page 510.
Matte, A. L. and J. R. Davey, Frequency Shift Telegraphy—Radio and Wire Applications, page 265.
Meacham, L. A. and E. Peterson, An Experimental Multichannel Pulse Code Modulation System of Toll Quality, page 1.
Mechanical Systems, Transients in, *J. T. Muller*, page 657.
Metallic Delay Lenses, *Winston E. Kock*, page 58.
Microwave Repeater Research, *H. T. Friis*, page 183.
Microwave Repeaters, The Measurement of Delay Distortion in, *D. H. Ring*, page 247.
Microwave Transmission: Metallic Delay Lenses, *Winston E. Kock*, page 58.
Microwaves: Reflections from Circular Bends in Rectangular Wave Guides—Matrix Theory, *S. O. Rice*, page 305.
Microwaves, A Non-reflecting Branching Filter for, *W. D. Lewis and L. C. Tillotson*, page 83.
Microwaves, Analysis and Performance of Wave Guide Hybrid Rings for, *H. T. Budenbom*, page 473.
Modulation, Pulse Code, Electron Beam Deflection Tube for, *R. W. Sears*, page 44.
Modulation System of Toll Quality, Pulse Code, An Experimental Multichannel, *L. A. Meacham and E. Peterson*, page 1.
Muller, J. T., Transients in Mechanical Systems, page 657.
Mumford, W. W., Maximally-Flat Filters in Wave Guide, page 684.

N

Networks, Linear Active Four-Terminal, Equivalent Circuits of, *L. C. Peterson*, page 593
Noise, Random, Statistical Properties of a Sine Wave Plus, *S. O. Rice*, page 109.
Noise in Resistances and Electron Streams, *J. R. Pierce*, page 158.

P

Peterson, E. and L. A. Meacham, An Experimental Multichannel Pulse Code Modulation System of Toll Quality, page 1.
Peterson, L. C., Equivalent Circuits of Linear Active Four-Terminal Networks, page 593.
Pierce, J. R., Noise in Resistances and Electron Streams, page 158. Transverse Fields in Traveling-Wave Tubes, page 732.
Pulse Code Modulation: Spectra of Quantized Signals, *W. R. Bennett*, page 446.
Pulse Code Modulation, Electron Beam Deflection Tube for, *R. W. Sears*, page 44.
Pulse Code Modulation System of Toll Quality, An Experimental Multichannel, *L. A. Meacham and E. Peterson*, page 1.

Q

Quartz Crystal Clock, The Evolution of the, *Warren A. Marrison*, page 510.

R

Radio: Transient Response of an FM Receiver, *M. K. Zinn*, page 714.
Radio and Wire Applications of Frequency Shift Telegraphy, *J. R. Davey and A. L. Matte*, page 265.
Random Noise, Statistical Properties of a Sine Wave Plus, *S. O. Rice*, page 109.
Receiver, an FM, Transient Response of, *M. K. Zinn*, page 714.
Repeater Research, Microwave, *H. T. Friis*, page 183.
Repeaters, Microwave, The Measurement of Delay Distortion in, *D. H. Ring*, page 247.
Rice, S. O., Reflections from Circular Bends in Rectangular Wave Guides—Matrix Theory, page 305. Statistical Properties of a Sine Wave Plus Random Noise, page 109.
Rideout, V. C., A Note on a Parallel-Tuned Transformer Design, page 96.
Ring, D. H., The Measurement of Delay Distortion in Microwave Repeaters, page 247.

S

Schelkunoff, S. A., Methods of Electromagnetic Field Analysis, page 487.
Schelkunoff, S. A. and Marion C. Gray, The Approximate Solution of Linear Differential Equations, page 350.
Sears, R. W., Electron Beam Deflection Tube for Pulse Code Modulation, page 44.
Shannon, C. E., A Mathematical Theory of Communication, pages 379–423; 623–656.
Signals, Quantized, Spectra of, *W. R. Bennett*, page 446.
Sine Wave Plus Random Noise, Statistical Properties of a, *S. O. Rice*, page 109.
Spectra of Quantized Signals, *W. R. Bennett*, page 446.
Statistical Properties of a Sine Wave Plus Random Noise, *S. O. Rice*, page 109.
Subscribers, An Aspect of the Dialing Behavior of, and Its Effect on the Trunk Plant, *Charles Clos*, page 424.

T

Telegraphy, Frequency Shift—Radio and Wire Applications, *J. R. Davey and A. L. Matte*, page 265.
Theory, A Mathematical, of Communication, *C. E. Shannon*, pages 379–423; 623–656.
Tillotson, L. C. and W. D. Lewis, A Non-reflecting Branching Filter for Microwaves, page 83.
Toll Transmission: An Experimental Multichannel Pulse Code Modulation System of Toll Quality, *L. A. Meacham and E. Peterson*, page 1.
Transformer Design, Parallel-Tuned, A Note on a, *V. C. Rideout*, page 96.
Transient Response of an FM Receiver, *M. K. Zinn*, page 714.
Transients in Mechanical Systems, *J. T. Muller*, page 657.
Transmission: A Mathematical Theory of Communication, *C. E. Shannon*, pages 379–423; 623–656.
Transverse Fields in Traveling-Wave Tubes, *J. R. Pierce*, page 732.
Traveling-Wave Tubes, Transverse Fields in, *J. R. Pierce*, page 732.
Trunk Capacity: An Aspect of the Dialing Behavior of Subscribers and Its Effect on the Trunk Plant, *Charles Clos*, page 424.
Trunk Plant, An Aspect of the Dialing Behavior of Subscribers and Its Effect on the, *Charles Clos*, page 424.

V

Vibration: Transients in Mechanical Systems, *J. T. Muller*, page 657.

W

Wave Guide, Maximally-Flat Filters in, *W. W. Mumford*, page 684.
Wave Guide Hybrid Rings for Microwaves, Analysis and Performance of, *H. T. Budenbom*, page 473.
Wave Guides, Rectangular, Reflections from Circular Bends in—Matrix Theory, *S. O. Rice*, page 305.
Wise, W. Howard, Potential Coefficients for Ground Return Circuits, page 365.

Z

Zinn, M. K., Transient Response of an FM Receiver, page 714.